patient setting. For outpatient procedures where volatile agents should probably be avoided (such as a midtrimester abortion), these adjunctive IV infusion techniques are simple to use and associated with a patient's rapid recovery and prompt discharge from the ambulatory surgery facility. With the increasing popularity of IV anesthetics, infusion pumps may soon become standard equipment on anesthesia machines.

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Perfluorochemical Emulsion—'Artificial Blood': What Is It?

LELAND CLARK dramatically proved the oxygen-carrying ability of perfluorochemicals by completely submerging a mouse in the liquid for 20 minutes and having it survive. These inert liquids have extremely high oxygen solubilities, about 20 times that of water—that is, 45 ml per dl at 760 torr oxygen partial pressure (tension; Po_2) and 37°C; perfluorochemicals are also immiscible in water and are acutely toxic when given intravenously because they form a bolus that acts as a pulmonary embolus. In 1968 it was shown that a fine emulsion of perfluorochemical in saline solution could act as an erythrocyte substitute in rats that have had exchange transfusions. The first human volunteers received the perfluorochemical emulsion, Fluosol-DA (20%), in 1979. Fluosol-DA has 14 grams per dl of perfluorodecalin and 6 grams per dl of perfluorotripropylamine emulsified in a solution of salts and hydroxyethyl starch. Because Fluosol-DA contains only 20 grams per dl of perfluorochemical with an approximate density of 1.8 grams per ml, in a patient having a complete exchange transfusion (fluorocrit about 12%, ml per dl of perfluorochemical in the plasma) at 500 torr arterial oxygen partial pressure (Pao_2), the perfluorochemical would carry about 6 ml per dl of oxygen. This may seem small compared with a normal arterial oxygen content of blood at room air of 20 ml per dl; but because the perfluorochemical transports oxygen by direct solubility as does plasma, nearly all the oxygen in the perfluorochemical is consumed. That is, if an exchange-transfused patient had an arterial-venous oxygen content difference of 4 ml per dl, the mixed venous Po_2 would be more than 150 torr.

Recent clinical studies in the United States and Japan have confirmed that perfluorochemicals do transport the expected volume of oxygen and in spite of the small amounts of perfluorochemical given (fluorocrit 3%), there were significant increases in oxygen content, oxygen consumption and mixed venous hemoglobin saturation. The perfluorochemical is cleared by expiration and has a plasma half-life of about 18 hours. As an erythrocyte substitute, perfluorochemical emulsions will only be beneficial in acute emergencies until blood is available. Because perfluorochemicals carry oxygen by simple solubility like plasma, the amount of oxygen carried is directly related to the Pao_2. It has been shown in a clinical study that a significant increase in oxygen content could only be measured when the perfluorochemical was in the presence of high Pao_2 values (more than 300 torr).

One of the most intriguing properties of perfluorochemical emulsions is the extremely small size of the emulsion droplets, 0.1 micron (1/70 the size of an erythrocyte). With the potential to transport more oxygen through small constricted blood vessels, these fluids may be beneficial in any acute ischemic disease process. Glogar and co-workers showed a significant myocardial protective effect when these fluids were given in an animal model of myocardial infarction. Peerless and colleagues found similar results in an animal model of acute cerebral ischemia.

Perfluorochemical emulsions are intriguing new fluids that should be thought of as "supercharged" plasma and not erythrocyte substitutes. They may support anemic patients but require high oxygen tensions. They will probably play a significant role in the future in emergency treatment of ischemic disease.

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Transcutaneous Oxygen Partial Pressure: A Continuous Noninvasive Monitor of Tissue Oxygenation

A TRANSCUTANEOUS OXYGEN SENSOR measures oxygen partial pressure (Po_2) noninvasively at the skin surface with the same Clark polarographic electrode that is used in conventional blood gas machines. For the sensor to record significant Po_2 values with fast response times on adult skin, the electrode must be heated to 44°C to 45°C. Heating the skin causes the stratum corneum to change structure, which is thought to increase its permeability to oxygen. Heating also causes hyperemia of the dermal capillary bed and is

said to "arterialize" the capillary blood. Therefore, the transcutaneous Po_2 sensor actually continually measures the Po_2 of heated skin tissue. This technique was first used on neonates in which transcutaneous Po_2 values were reported to nearly equal arterial oxygen tensions (Pao_2). Transcutaneous Po_2 monitoring has now become a standard tool for managing neonates with respiratory distress syndrome.

By the late 1970s it had been noted that transcutaneous Po_2 values were very low in neonates who were hemodynamically compromised. At first these low values were considered faulty and transcutaneous Po_2 monitoring was reported to be "unreliable" during shock states. In 1979 it was shown in animal models that transcutaneous Po_2 follows Pao_2 during hypoxia and follows changes in cardiac output and oxygen delivery during hypovolemic shock and resuscitation. These results have been confirmed in clinical studies of adults. It is now realized that transcutaneous Po_2 values are peripheral tissue oxygen tensions and therefore are more related to changes in oxygen delivery. These values will follow those of Pao_2 when cardiac output is adequate and follow cardiac output and oxygen delivery during low cardiac output, shock and resuscitation. The normal values in adults are about 80% of the Pao_2 when patients are hemodynamically stable (transcutaneous Po_2 [$Ptco_2$] index = $Ptco_2/Pao_2 = 0.79 \pm 0.12$ when cardiac index is more than 2.2 liters per minute per m^2). As cardiac output decreases, the central-to-peripheral-oxygen gradient increases such that the transcutaneous Po_2 is about 50% of Pao_2 when the cardiac index is about 2 liters a minute per m^2 and it is about 10% of Pao_2 when the cardiac index is about 1 liter a minute per m^2 (Table 1).

TABLE 1.—*Transcutaneous Oxygen Partial Pressure ($PtCO_2$) Versus Arterial Oxygen Pressure (PaO_2) Linear Regression Values and $PtCO_2$ Index Values for Patients Grouped in 3 Ranges of Cardiac Index (CI)**

	Group 1 Stable CI>2.2	*Group 2 Moderate Shock 2.2>CI>1.5*	*Group 3 Severe Shock CI<1.5*
No. Data Sets/ No. Patients ...	934/92	74/5	65/9
Cardiac index (l/min per m^2) .	4.10± 1.00	2.00± 0.20	0.90± 0.20
Mean arterial pressure (mm of mercury)	96.00±17.00	94.00±18.00	39.00±21.00
$Ptco_2$ v Pao_2 linear regression			
r-Value	0.89	0.78	0.06
Slope	0.78	0.50	....
Intercept	4.10	6.00	....
$Ptco_2$ index	0.79± 0.12	0.48± 0.07	0.12± 0.12

*Adapted from Tremper and Shoemaker, 1981.

The in vitro response times of the electrodes are very fast, 95% response in 10 to 20 seconds. The in vivo 95% response of the sensors to changes in inspired oxygen are in the range of two to three minutes, but this lag in response is for the physiologic transport of oxygen to the tissues.

Transcutaneous Po_2 sensors have now been shown to be reliable continuous noninvasive monitors of tissue oxygenation. These values reliably follow the Pao_2 values when the patients are hemodynamically stable and give an assessment of the degree of tissue hypoxia and hypoperfusion during shock and resuscitation. The transcutaneous Po_2 monitor is undoubtedly a significant advance in noninvasive patient monitoring.

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Anesthetic Management of Chymopapain Injections

EACH YEAR ABOUT 200,000 surgical procedures are performed on patients with "low back pain syndrome." Chemonucleolysis, the injection of chymopapain into a herniated disc, offers an alternative intervention in selected patients. However, there is a 1% incidence of an anaphylactic reaction and a 0.1% chance of a fatal outcome. Chymopapain is now available in a purified form, Chymodiactin, and it produces relief of symptoms in 75% of properly selected patients. Chymodiactin is composed of two proteins that are stabilized with sodium cysteinate hydrochloride. Chymopapain hydrolyzes the mucopolysaccharide nucleus pulposus. Chemonucleolysis may be done under general endotracheal or local anesthesia supplemented with sedation or analgesia (or both).

The risk is the development of anaphylactic or anaphylactoid reactions. Anaphylaxis usually requires a previous exposure (chymopapain is used in some nonmedical commercial products) of a patient's lymphocytes to produce IgE-mediated release of histamine and other active substances that dilate arterioles and venules and increase capillary permeability, with massive loss of intravascular fluids and profound hypotension. In addition, bronchospasm, ventricular dysrhythmias, atrioventricular block and coronary arterial spasm may ensue. Anaphylactoid reactions are effected by a direct action on mast cells and basophils producing histamine release and the clinical manifestations may be milder or indistinguishable from those of anaphylaxis.

Patient selection for an allergic diathesis is mandatory: a history of either atopy or allergic drug reactions is a relative contraindication. Women have a fourfold greater chance of a reaction than do men.